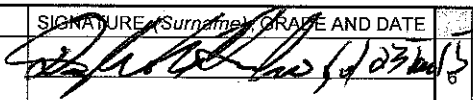


## STAFF SUMMARY SHEET

	TO	ACTION	SIGNATURE (Surname), GRADE AND DATE		TO	ACTION	SIGNATURE (Surname), GRADE AND DATE
1	USAFA/DFAN	sig	 4/23/15	6			
2	USAFA/DFER	approve	SOJL, ADZS, 27 Jan 15	7			
3	USAFA/DFAN	action	(Author / Originator)	8			
4				9			
5				10			

SURNAME OF ACTION OFFICER AND GRADE

SYMBOL

PHONE

TYPIST'S  
INITIALS

SUSPENSE DATE

Decker, Ctr

USAFA/DFAN

333-7987

rkd

20150128

SUBJECT

Clearance for Material for Public Release

USAFA-DF-PA- 011

DATE

20150123

## SUMMARY

1. PURPOSE. To provide security and policy review on the document at Tab 1 prior to release to the public.

## 2. BACKGROUND.

Authors: Andrew J. Lofthouse, Robert K. Decker

Title: FieldView Educational Use at USAFA 2014

Circle one: Abstract Tech Report Journal Article Speech Paper Presentation Poster

Thesis/Dissertation Book Other: \_\_\_\_\_

Check all that apply (For Communications Purposes):

☐ CRADA (Cooperative Research and Development Agreement) exists☐ Photo/ Video Opportunities ☐ STEM-outreach Related ☐ New Invention/ Discovery/ Patent

Description: Statement of FieldView Educational Use at USAFA during calendar year 2014

Release Information: Intelligent Light, 301 Route 17 North, 7th Floor, Rutherford, NJ 07070

Previous Clearance information: None

Recommended Distribution Statement: Distribution A, Approved for Public release, distribution unlimited.

## 3. DISCUSSION. N/A

4. RECOMMENDATION. Sign coord block above indicating document is suitable for public release. Suitability is based solely on the document being unclassified, not jeopardizing DoD interests, and accurately portraying official party.

  
 ANDREW J. LOFTHOUSE, Lt Col, USAF  
 Director, High Performance Computing Research Center

2 Tabs

1. FieldView Educational Use at USAFA 2014

2. Attachment to FieldView Educational Use at USAFA 2014

**FieldView Education License Usage Annual Report**  
**U.S. Air Force Academy**  
**20 January 2015**  
**Lt Col Andrew Lofthouse**

1) List of publications where FieldView images were used:

Fagley, C., Porter, C., and McLaughlin, T., "Curvature Effects of a Cycloidally Rotating Airfoil," 52<sup>nd</sup> Aerospace Sciences Meeting, AIAA Paper 2014-0255, January 2014.

Porter, C., Fagley, C., Seidel, J., and McLaughlin, T., "Closed-Loop Flow Control on a Ogive Forebody at a High Angle of Attack using Model Predictive Control," 52<sup>nd</sup> Aerospace Sciences Meeting, AIAA Paper 2014-0930, January 2014.

Porter, C., Fagley, C., Farnsworth, J., Seidel, J., and McLaughlin, T., "Closed-Loop Flow Control of a Forebody at a High Incidence Angle," AIAA Journal, Vol. 52, No. 7, 2014, pp. 1430-1440.

Ghoreyshi M., Jirasek, A., and Cummings, R., "Reduced Order Unsteady Aerodynamic Modeling for Stability and Control Analysis Using Computational Fluid Dynamics," Progress in Aerospace Sciences, Vol. 71, 2014, pp. 167-217.

Ghoreyshi, M., and Cummings, R., "Unsteady Aerodynamics Modeling for Aircraft Maneuvers: a New Approach Using Time-Dependent Surrogate Modeling," Journal of Aerospace Science and Technology, Vol. 39, 2014, pp. 222-242.

Bergeron, K., Seidel, J., Ghoreyshi, M., Jirasek, A., and Cummings, R., "Numerical Study of Ram Air Airfoils and Upper Surface Bleed-Air Control," 32nd AIAA Applied Aerodynamic Conference, AIAA Paper 2014-2832, June 2014.

Ghoreyshi, M., Seidel, J., Bergeron, K., Jirasek, A., Lofthouse, A., and Cummings, R., "Prediction of Aerodynamic Characteristics of a Ram-Air Parachute," 32nd AIAA Applied Aerodynamic Conference, AIAA Paper 2014-2831, June 2014.

Ghoreyshi, M., Young, M., Jirasek, A., Lofthouse, A., and Cummings, R., "Validation of Unsteady Aerodynamic Models of a Generic UCAV Configuration," 32nd AIAA Applied Aerodynamic Conference, AIAA Paper 2014-2265, June 2014.

Lofthouse, A., Ghoreyshi, M., Cummings, R., and Young, M., "Static and Dynamic Simulations of a Generic UCAV Geometry Using the Kestrel Flow Solver," 32nd AIAA Applied Aerodynamic Conference, AIAA Paper 2014-2264, June 2014.

Young, M., Ghoreyshi, M., Jirasek, A., and Cummings, R., "Prediction and Validation of Aerodynamic Characteristics for a Generic UCAV Configuration with Trailing-Edge Flaps," 32nd AIAA Applied Aerodynamic Conference, AIAA Paper 2014-2136, June 2014.

Ghoreyshi, M., Kim, A., Jirasek, A., Lofthouse, A., and Cummings, R., "Validation of CFD Simulations For X-31 Wind Tunnel Models," 52nd AIAA Aerospace Science Meeting, AIAA Paper 2014-0048, 13-17 January 2014.

2) Image files (at high resolution if possible): see attachment hosted on ftp site.

3) Description of how the FieldView licenses were used in your teaching or research:

FieldView was used in two courses during the past year: AE342 (Computational Aerodynamics) and AE472 (Advanced Computational Aerodynamics). AE342 is an introductory course in CFD where cadets learn basic use of grid generation, flow solver, and flow visualization software to perform two projects: a viscous 2D airfoil project and an inviscid 3D wing project. A FieldView tutorial is completed by all cadets (approximately 70 cadets take the course per year). Cadets in AE472 perform research with faculty on DoD HPC computers and present their results at the end of the semester. There were a total of 7 cadets in AE472 this past year who conducted research on a B-52 aircraft, a KC-135 aircraft, a generic transonic cruise configuration, a propulsive wing, store separation, starting/stopping characteristics of the USAFA Mach 6 Ludwig Tube, and characterization of USAFA's turbine cascade wind tunnel. Some select cadets also participate in our Cadet Summer Research Program (CSRP) or Independent Study (AE499), where they continue their research from AE472 or conduct similar research projects.

In addition, numerous researchers in the Aeronautics Research Center and the High Performance Computing Research Center use FieldView on a regular basis. Their research is overviewed in the papers listed above, and includes stability and control modeling, tangent ogive noses at high angles of attack, aerodynamic simulations of a generic UCAV and the X-31, a cycloidally rotating airfoil, ram air parachutes, and educational research. Detailed descriptions are included below for most of these projects.

**Stability and Control Modeling:** Our research is focused on identifying and developing high-fidelity reduced order models that capture the nonlinear and unsteady aerodynamic characteristics of air vehicles with moving control surfaces using overset grids. Test cases this year considered a fighter configuration and a generic UCAV to provide a mix of aerodynamic, flow control, and flight dynamic challenges. The aerodynamic responses of these vehicles to different motions and control surface movements are visualized in FieldView. This gives us a unique advantage of investigating the flowfield around the air vehicles at each instant of time spent in maneuvers. These flowfield measurements in wind tunnel or flight tests can be a complicated task that involves many compromises. These tests can only measure a limited time history of flowfield around a maneuvering aircraft. In addition, flight tests are potentially dangerous to perform a full investigation of the aircraft operational flight envelope especially maneuvering at high angles of attack. Another advantage of using FieldView in our research is the methods available in FieldView that can detect and highlight flow features such as shock, flow separation, and vortices.

**Tangent Ogive Nose:** The flow field around a slender axisymmetric forebody varies dramatically with the angle of attack. Typically, four flow regimes are observed: attached flow, symmetric

vortex flow, asymmetric vortex flow, and unsteady wake-like flow. The transition between the symmetric and asymmetric vortex flow is due to an instability of the natural flow field. Minor geometric imperfections and flow perturbations are amplified by this convective instability and divert the flow field away from the symmetric vortex state into an asymmetric vortex state. This phenomenon will cause either the port or starboard vortex to separate from the forebody surface, producing a large asymmetric pressure distribution on the surface or side force. The natural tendency of the flow field to favor an asymmetric vortex state emphasizes the importance of forebody vortex management. Closed-loop active flow control techniques hold the promise to increase stability and improve maneuverability characteristics of slender bodies at high angles of attack at varying flow conditions. In fact, a unique approach, developed at the USAF Academy, to formulating closed-loop control algorithms is employed to control the asymmetric vortex phenomenon through the convective instability.

Cycloidally rotating airfoil: A cycloidally (including prolate, curtate and traditional cycloids) rotating airfoil (CRA) has very unique aero/hydrodynamic characteristics, unlike any other device which interacts with a surrounding fluid flow. A system employing a CRA is one where the airfoil is mounted such that the span is aligned parallel with the axis of rotation, which is different to conventional rotors where the blades are oriented perpendicularly to the axis of rotation. This fundamental difference between the two aero-interactive systems provides CRAs the ability to interact with the incoming fluid flow in any direction perpendicular to the axis of rotation. Thus, from a propulsion standpoint, this unique characteristic allows the system to generate thrust in any direction perpendicular to the main shaft. Conversely, from an energy extraction standpoint, the device is able to generate shaft torque with any directional freestream perpendicular to the rotational axis. However, despite these stark advantages of these unique devices, many complex and poorly understood aero/hydrodynamic challenges are also procured. For instance, aerodynamic complexities such as: virtual camber, radial velocity (pressure) gradients, blade-wake interaction, and highly unsteady pitch-heave motions can be identified. The research assessed a tier of computational fluid dynamic tools (complex potential, panel methods, and Navier-Stokes simulations) to illustrate the effects of curvature on a CRA. A non-dimensional parameter, regarding relative curvature, is formulated which relates resulting lift to arbitrary airfoil shapes with a constant curvature. Additionally, it is found that the attachment location, or pivot point, of the airfoil is a critical factor, and, interestingly, a three quarter chord attachment location produces a zero lift for all relative curvatures.

Ram air parachutes: Natick Soldier Research, Development, and Engineering Center has been leading a Modeling and Simulation effort to develop high fidelity simulations of ram-air parachute systems to complement the design and analysis of new and existing airdrop systems. In this paper an unsteady numerical study of two-dimensional, rigid, ram-air sections with an array of upper surface bleed-air actuators is presented. Aerodynamic forces and lift-to-drag ratios of a modified Clark-Y ram-air airfoil are calculated from unsteady Reynolds-Averaged Navier-Stokes (RANS) simulations, using the Kestrel and Cobalt flow solvers. The flow fields exhibit a complicated cavity flow coupling with the airfoil profile. Variations in the locations and number of bleed air actuators and trailing edge deflection yield time averaged L/D values between 1.24 and 59.14, and strongly support the utility of the bleed air actuators for use as an enhanced lateral/longitudinal control mechanism. Additionally, these initial results emphasize the

requirements for prudent mesh generation and the performance of unsteady calculations for ram-air canopy simulations.

4) Computer systems used:

USAFA SGI cluster with 12 nodes, each node consisting of two six-core Intel Xeon X5650 (2.67GHz) processors and 4 GB of memory per core, resulting in 144 total cores (used for AE342, AE372, and some research)

Various DoD HPC computers including Spirit, Garnet, Riptide, etc.

5) CFD Solvers:

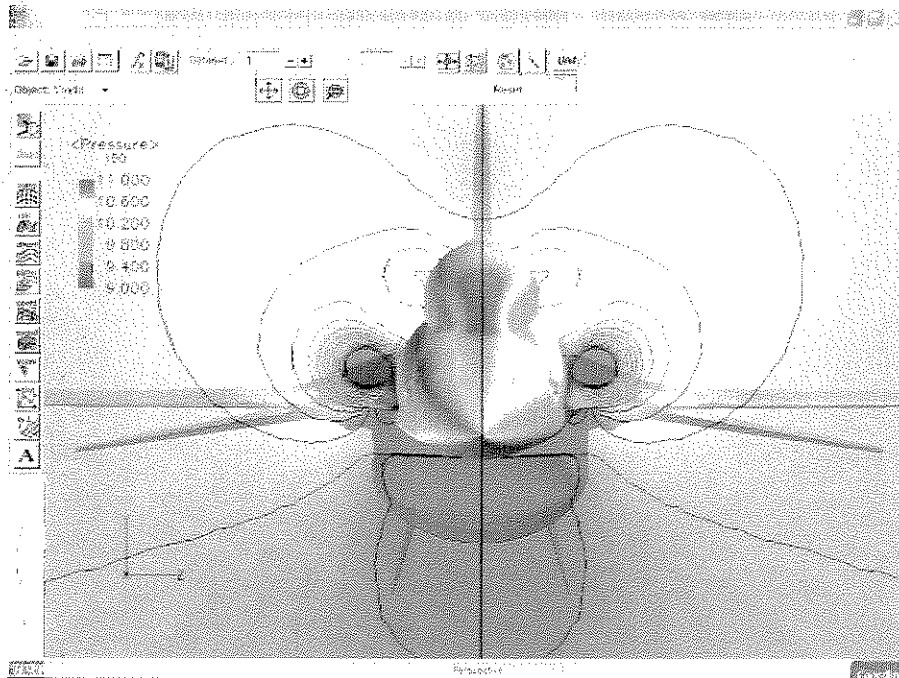
Primarily Cobalt and Kestrel

## Attachment to USAFA FieldView Education License Usage Annual Report

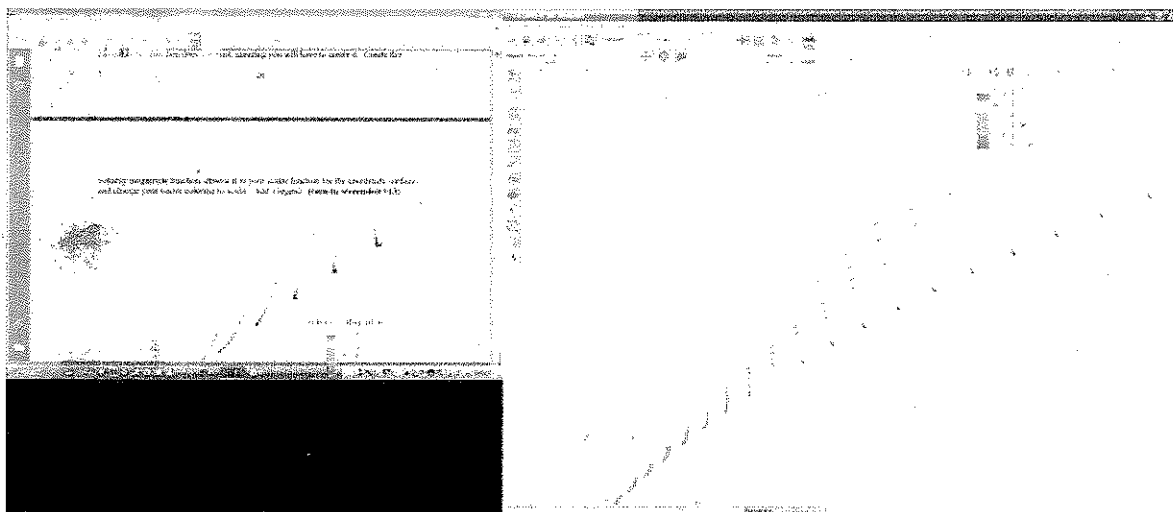
### FieldView Images

#### AE 342 – Computational Aerodynamics

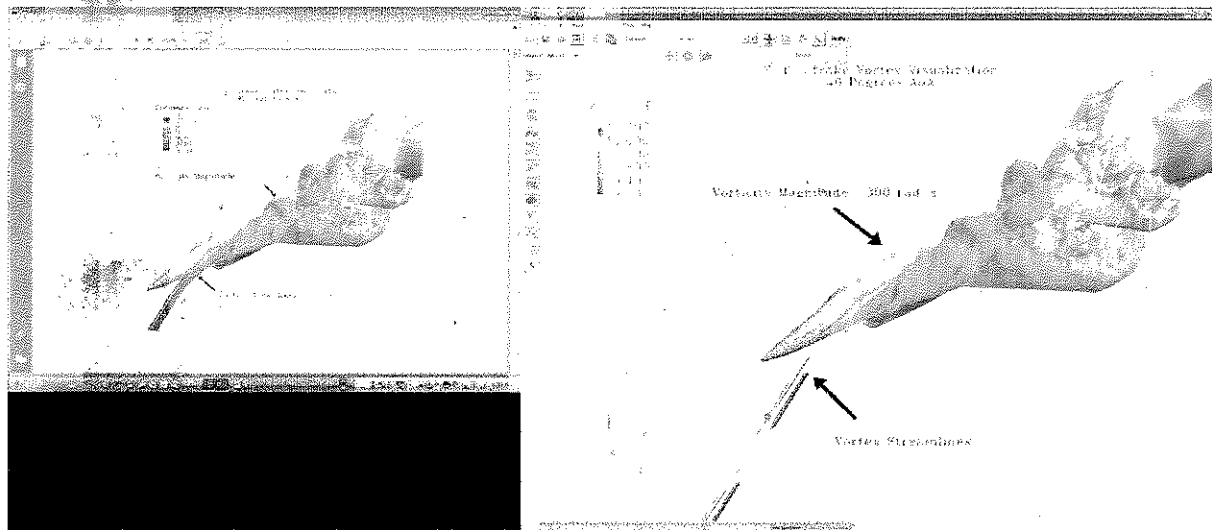
Examples of student work from the junior-level Computational Aerodynamics course. Students begin by taking a given flow solution and analyzing it to get familiar with FieldView capabilities.



Pressure contours on an F-16

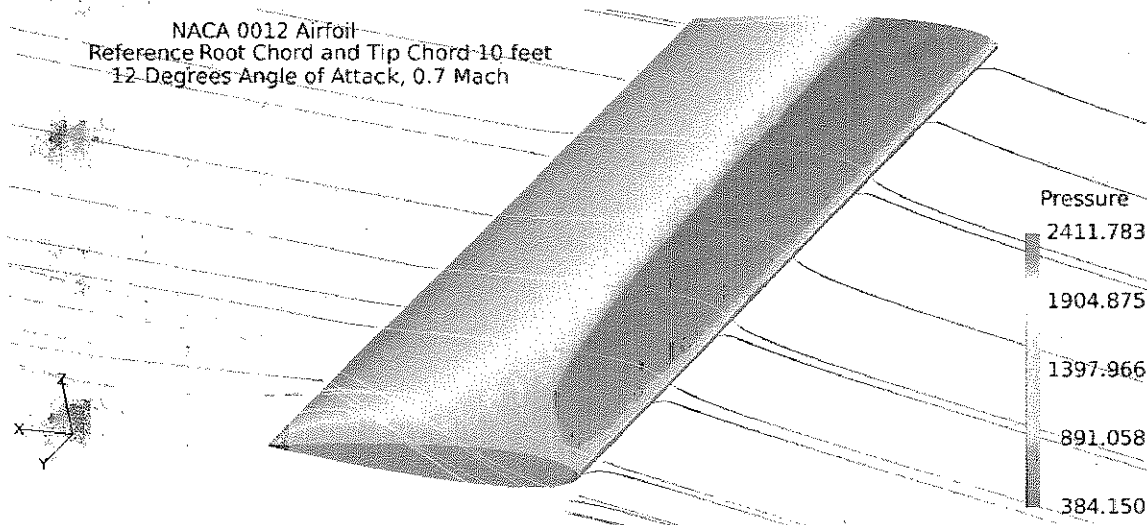


Boundary layer using velocity vectors



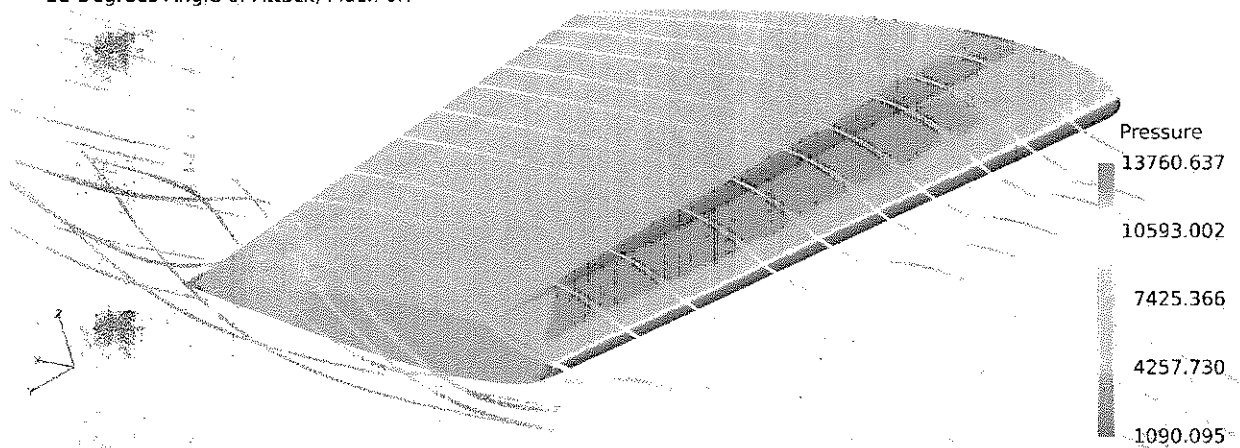
Vortex visualization

Students then compute solutions for an inviscid 3D wing.



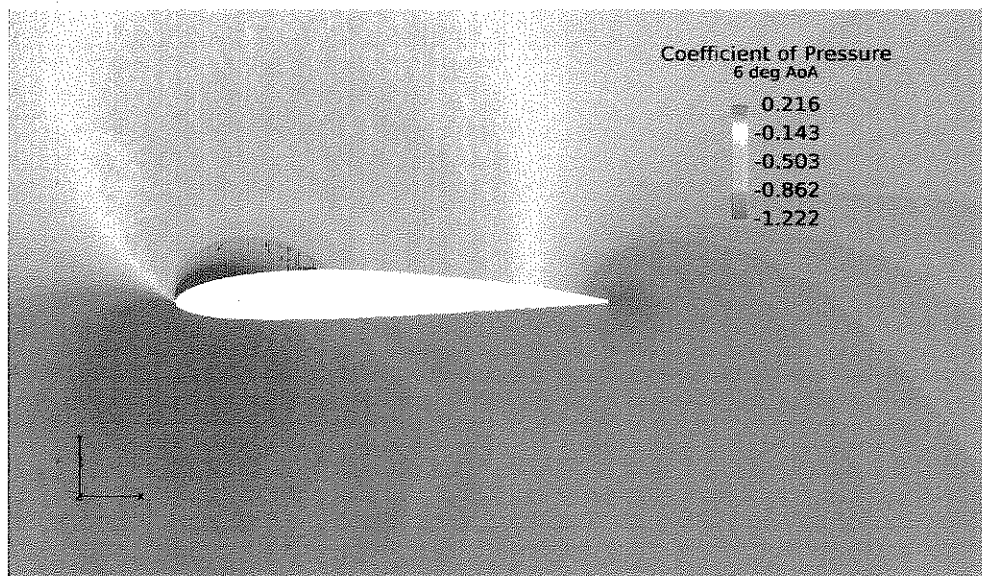
Pressure distribution over wing with taper ratio of 1 at  $12^\circ$  angle of attack and Mach 0.7

NACA 0012 Airfoil  
 Root Chord 15 feet, Tip Chord 10 feet  
 12 Degrees Angle of Attack, Mach 0.7



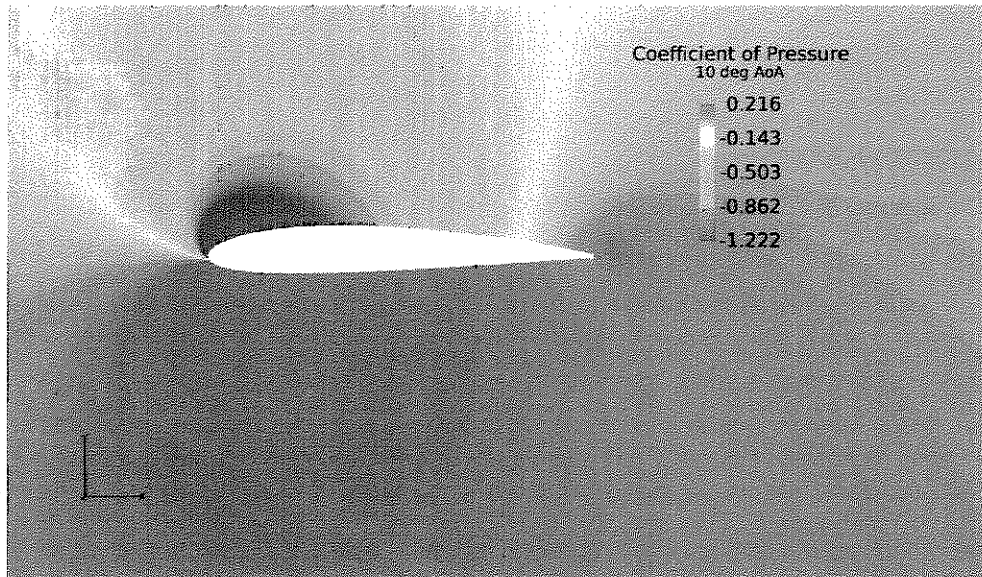
Pressure distribution over wing with a taper ratio of .666 at 12° angle of attack and Mach 0.7

Students finish the class with an analysis of a viscous airfoil.

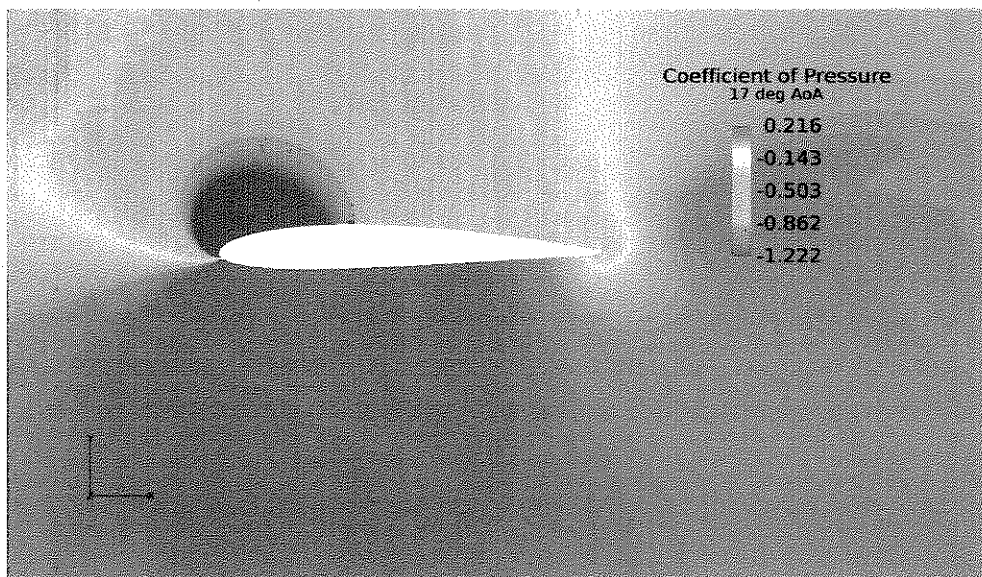


Coefficient of Pressure – NACA 2412 airfoil at 6° AoA



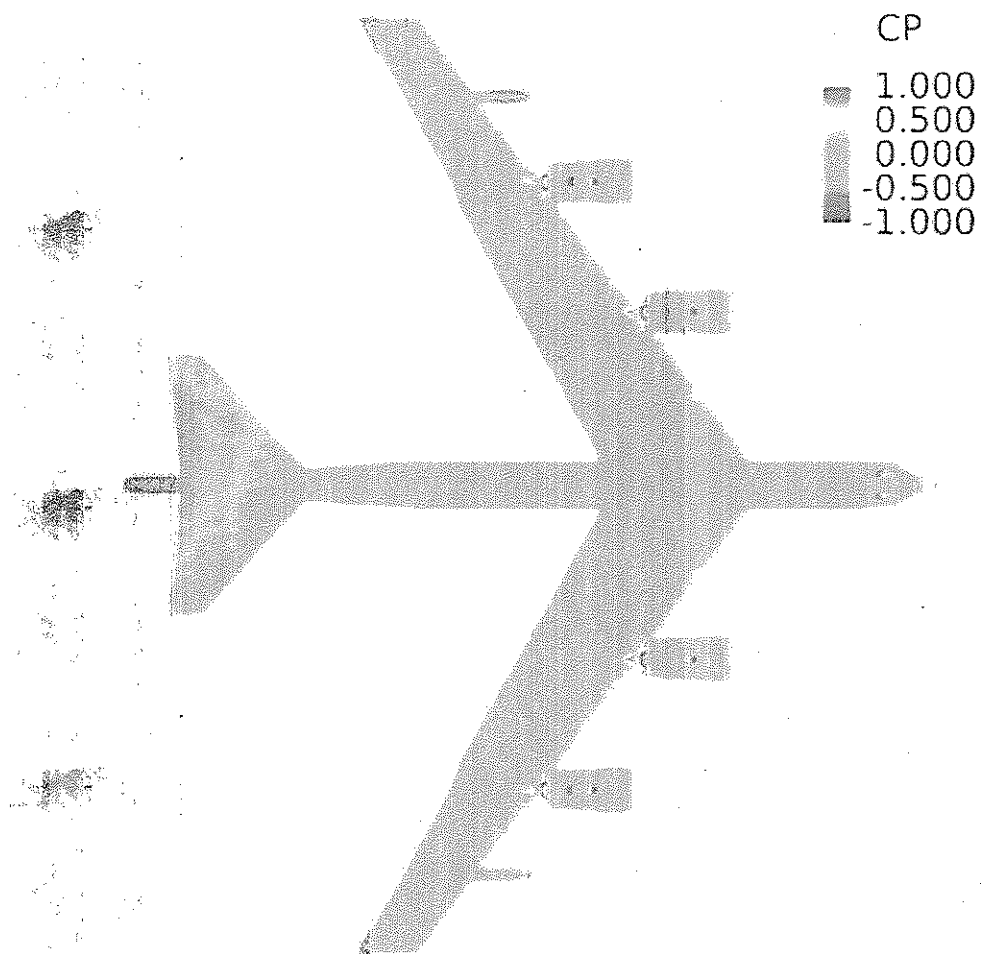


Coefficient of Pressure – NACA 2412 airfoil at 10° AoA

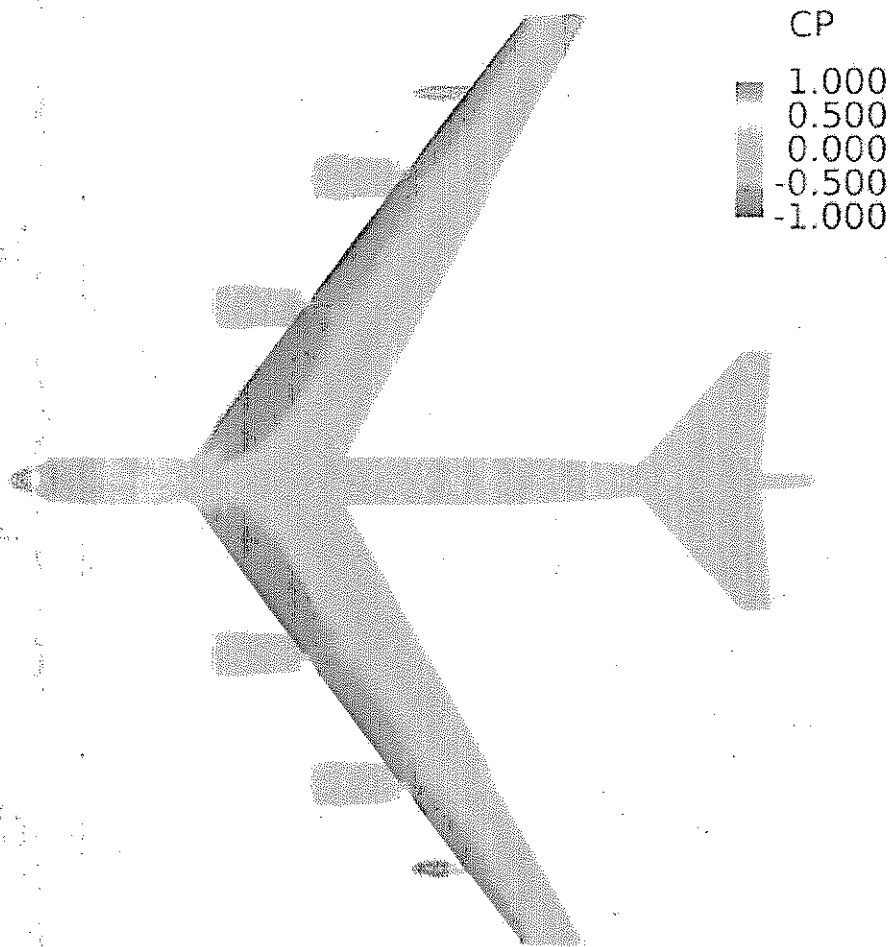


Coefficient of Pressure – NACA 2412 airfoil at 17° AoA

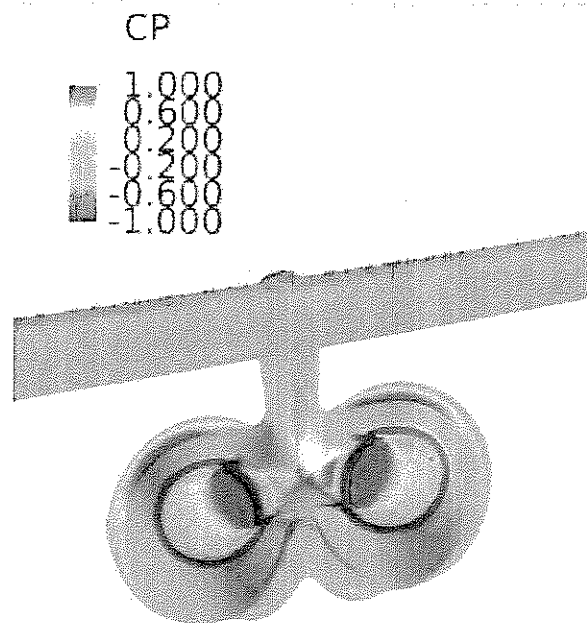
**Cadet Research (AE 472 – Advanced Computational Aerodynamics, AE 499 Independent Study, and Cadet Summer Research Program)**



Bottom surface pressure coefficient for B-52 in cruise.

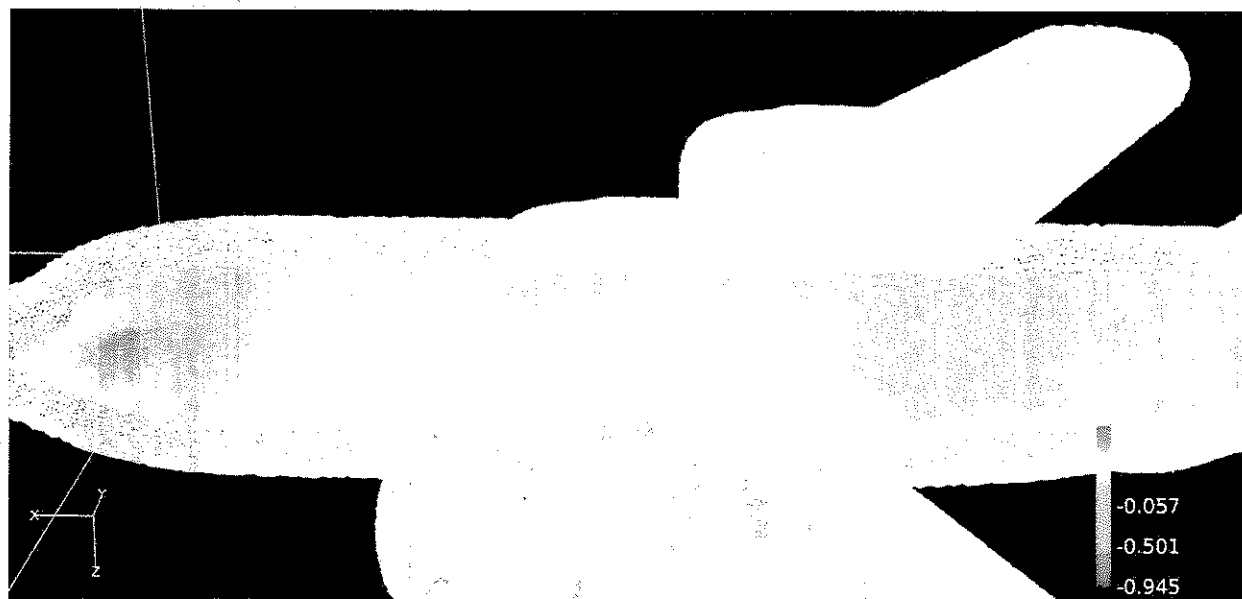


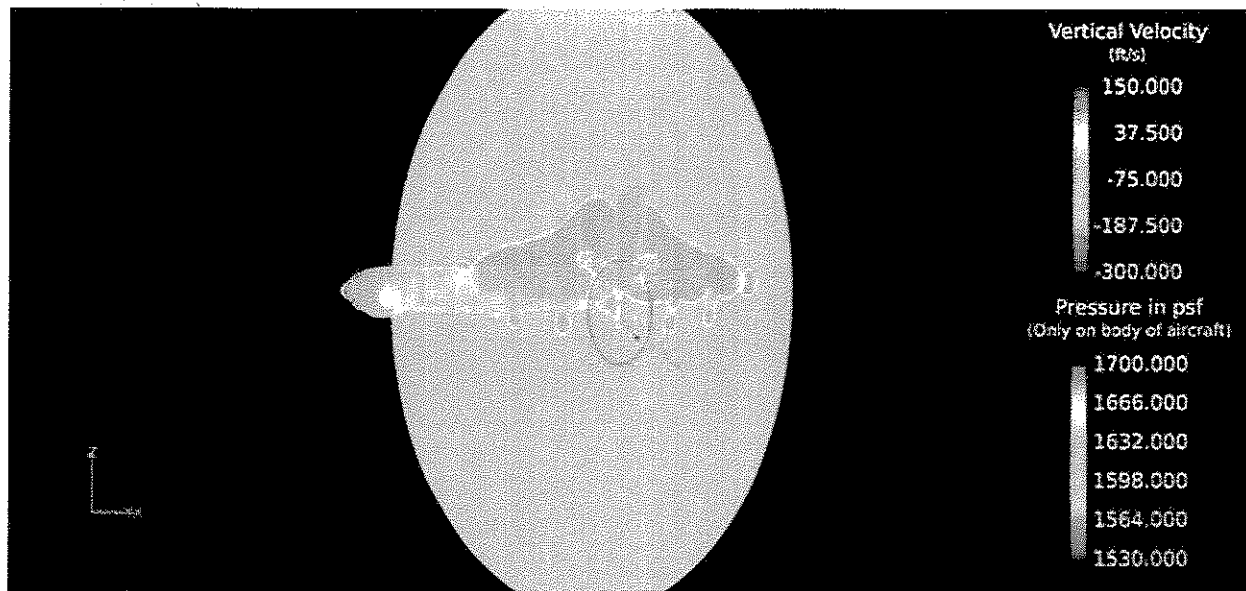
Top surface pressure coefficient for B-52 in cruise.



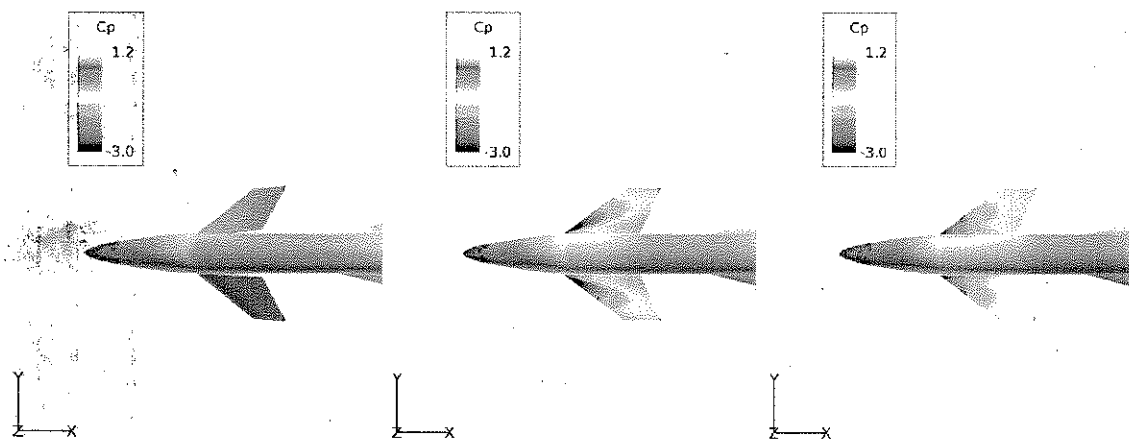
Pressure coefficient at engine exhaust plane for B-52 in cruise.

KC-135

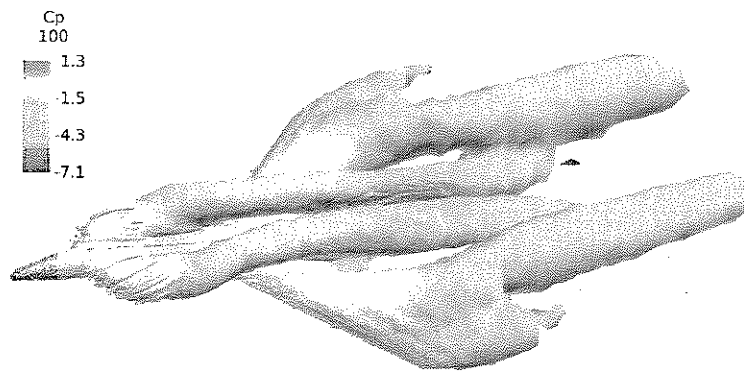




Transonic cruiser

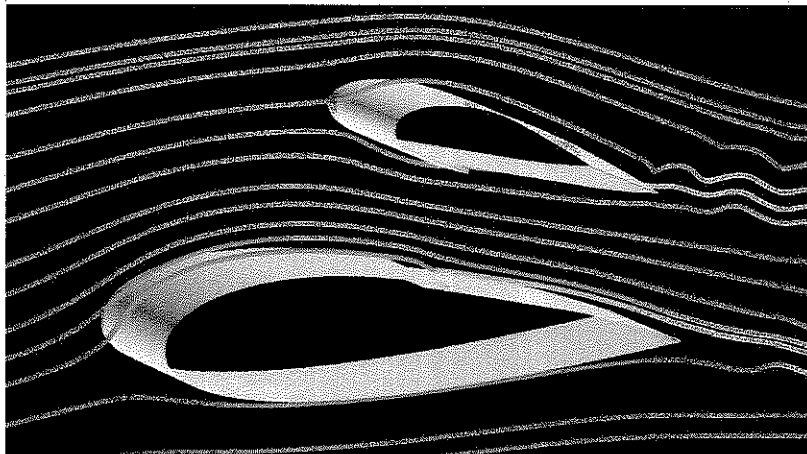


Comparison of surface pressure coefficient at different canard deflection angles for transonic cruiser

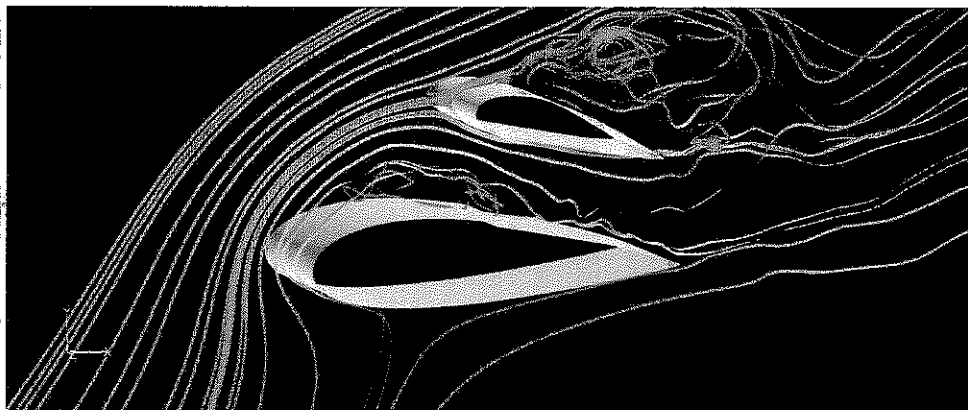


Iso-surface of vorticity on transonic cruiser.

### Propulsive Wing

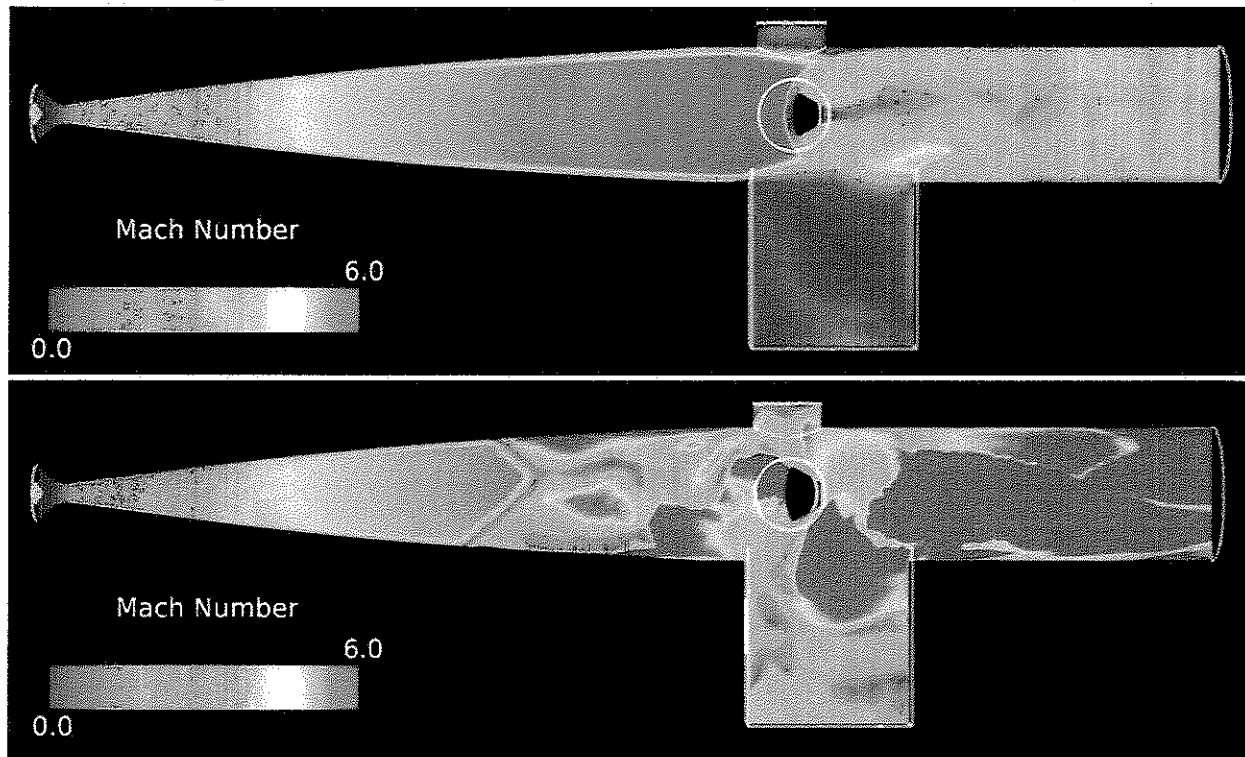


Streamlines at 0 degrees angle of attack

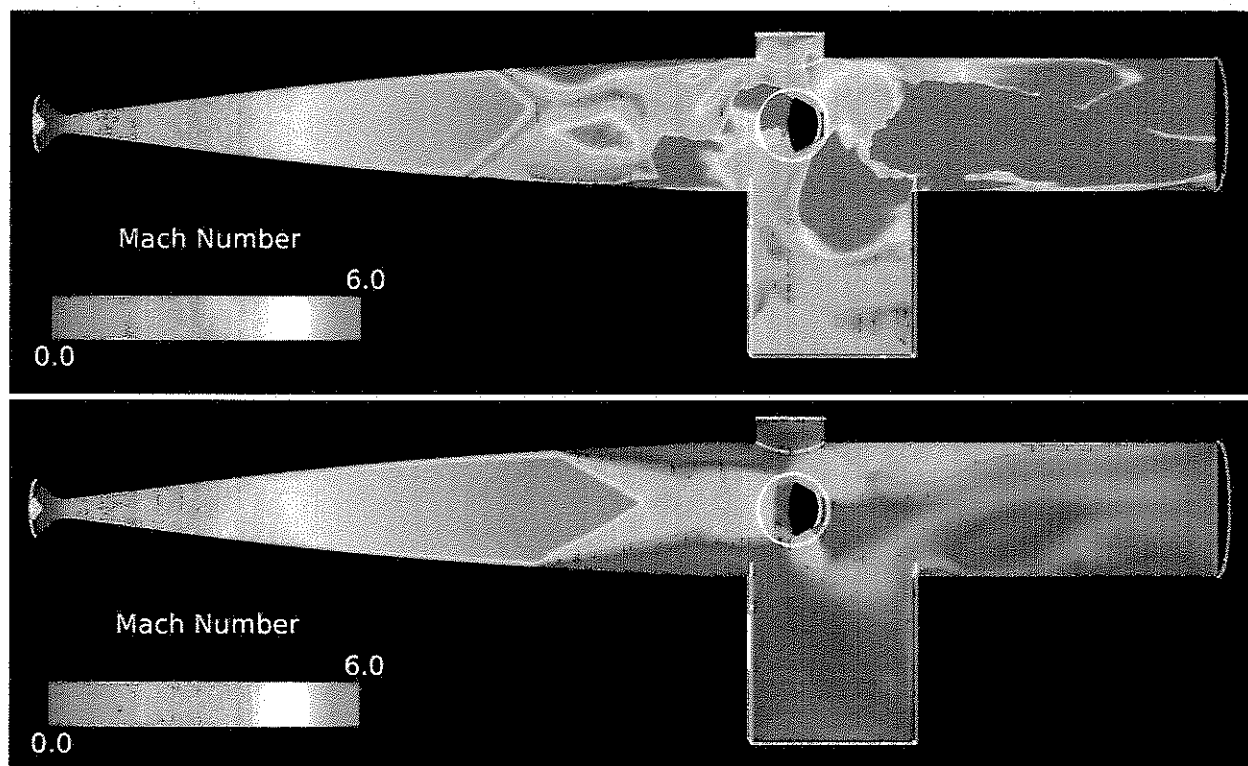


Streamlines at 35 degrees angle of attack

Mach 6 Ludwig tube

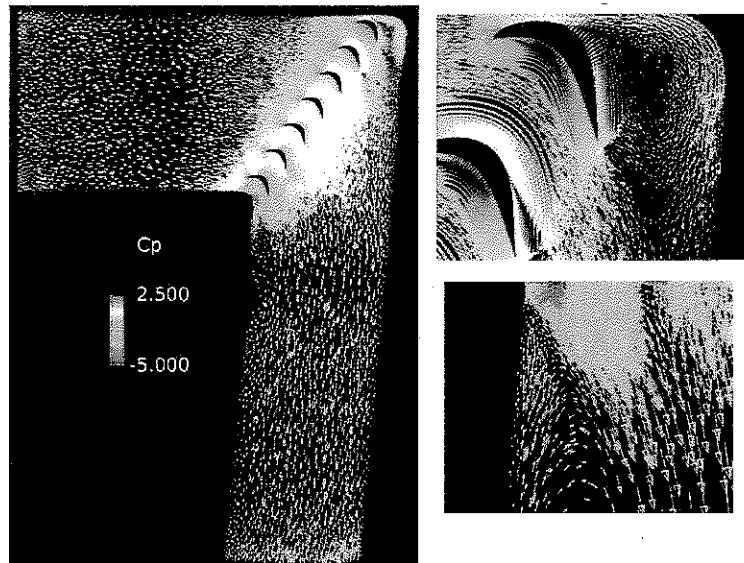


Comparison of flow state between 160mm test article (top) and 200mm test article (bottom)



Comparison of inflow pressure on 200mm test article. 15 bar inflow (top) and 30 bar inflow (bottom)

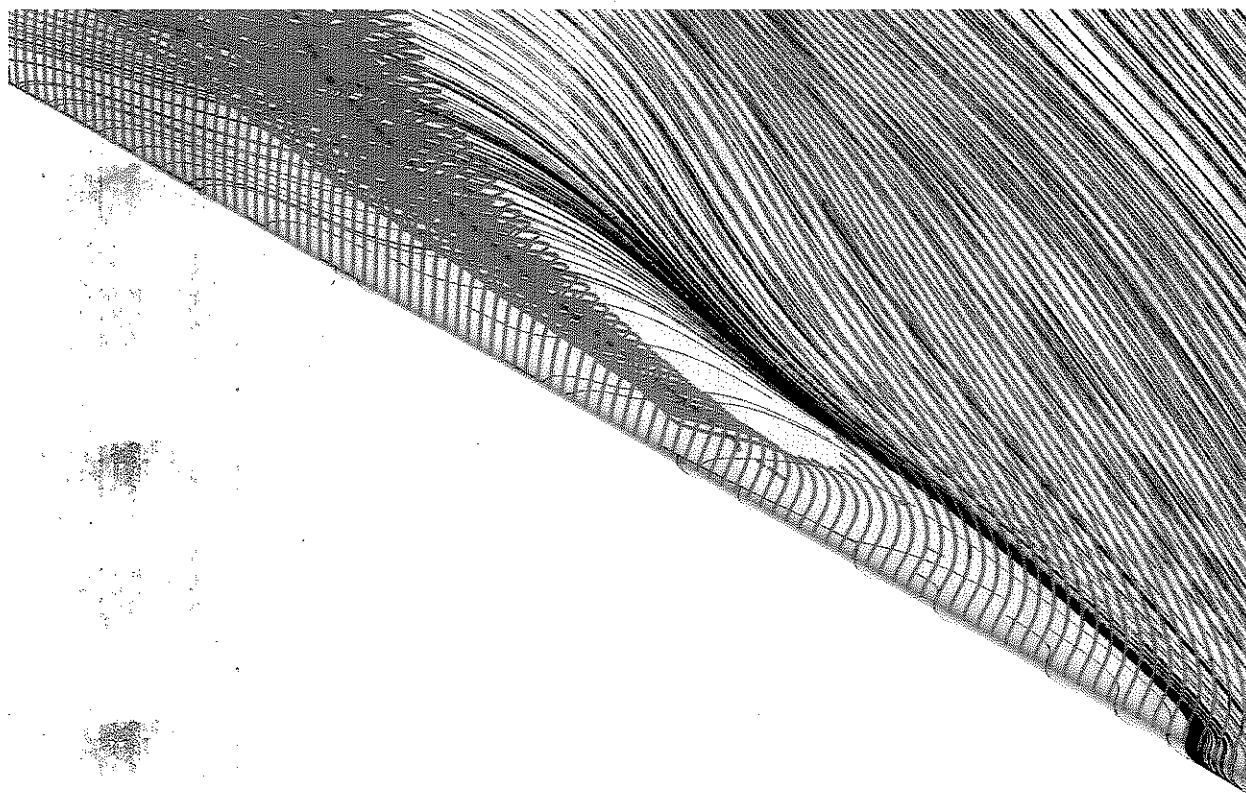
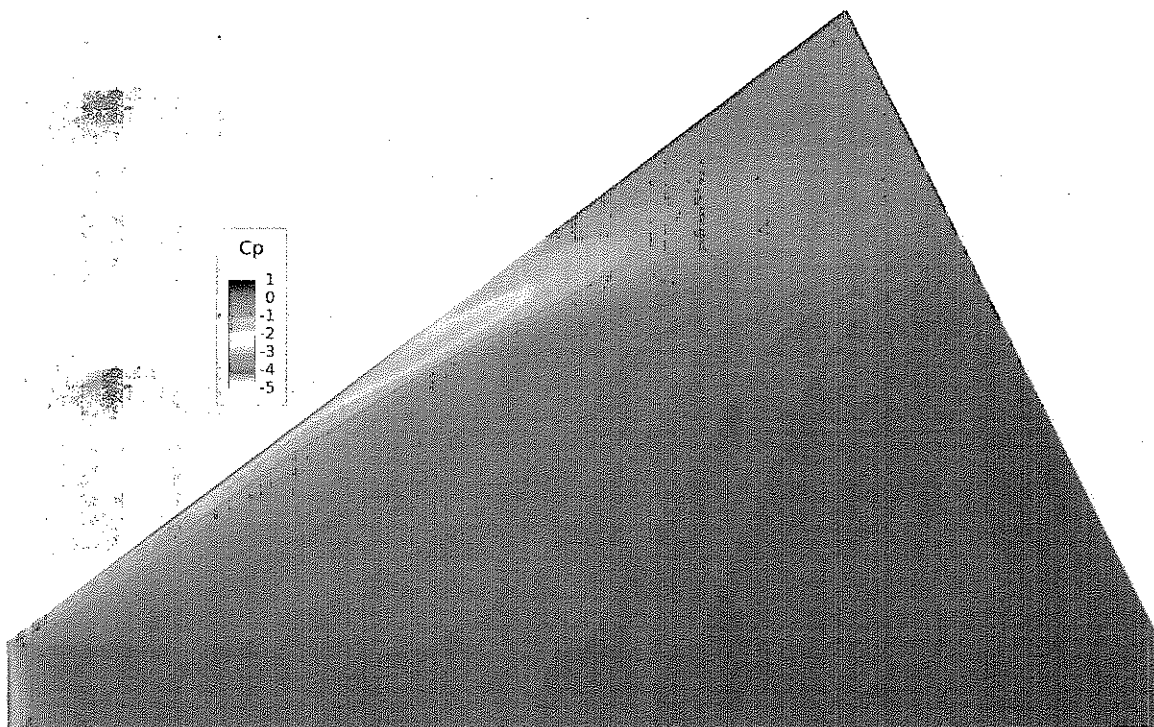
Cascade wind tunnel

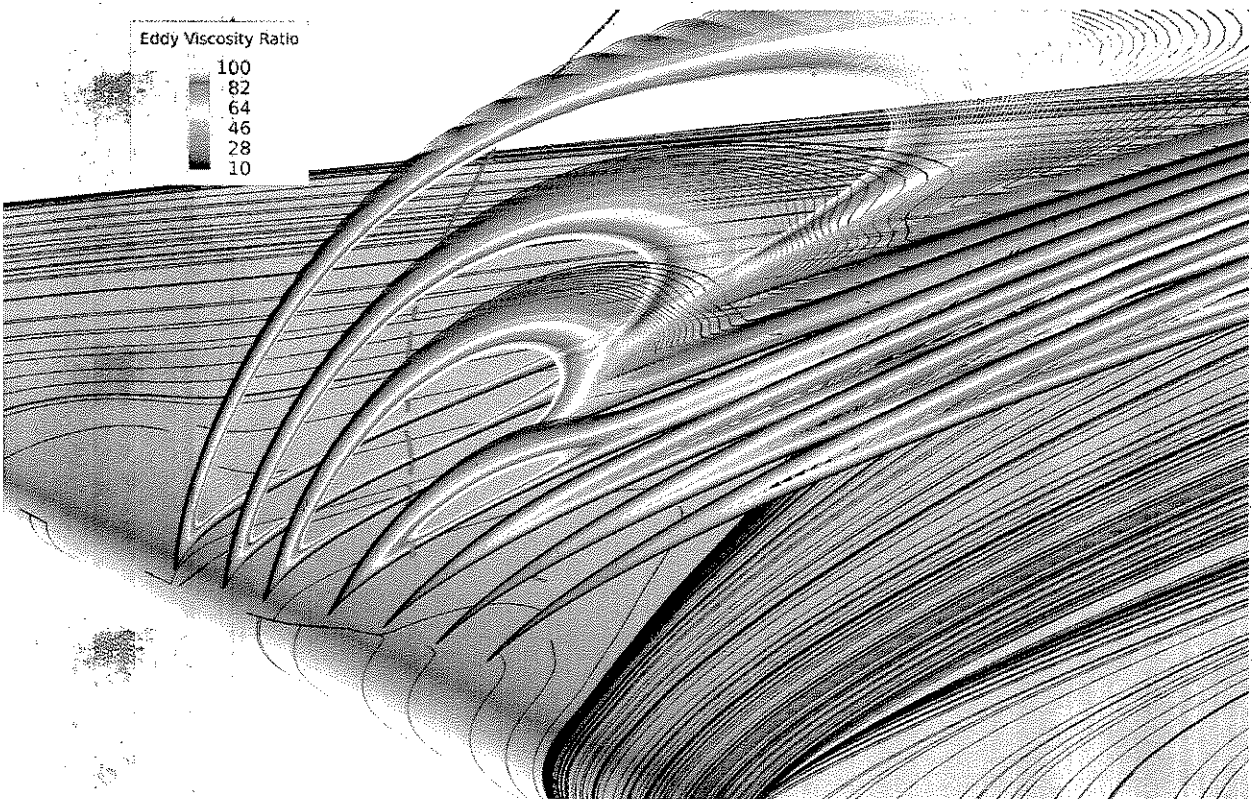
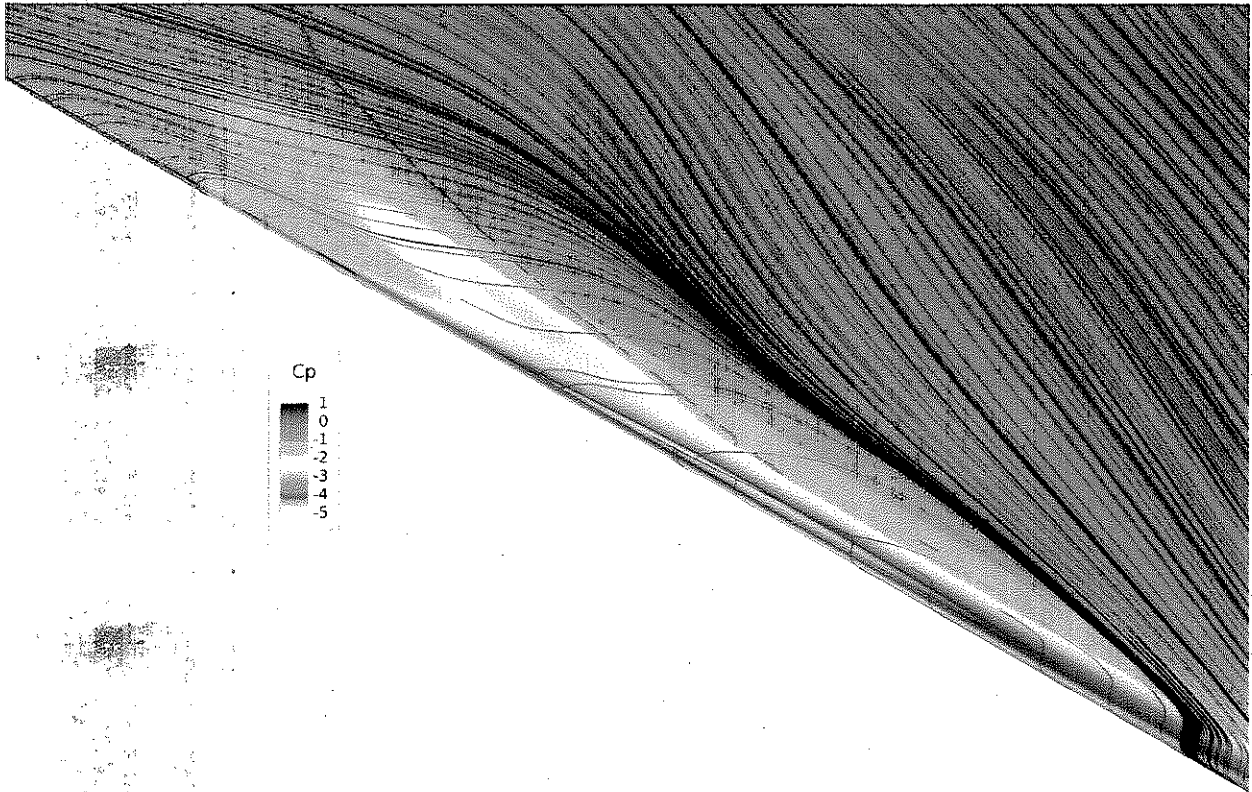


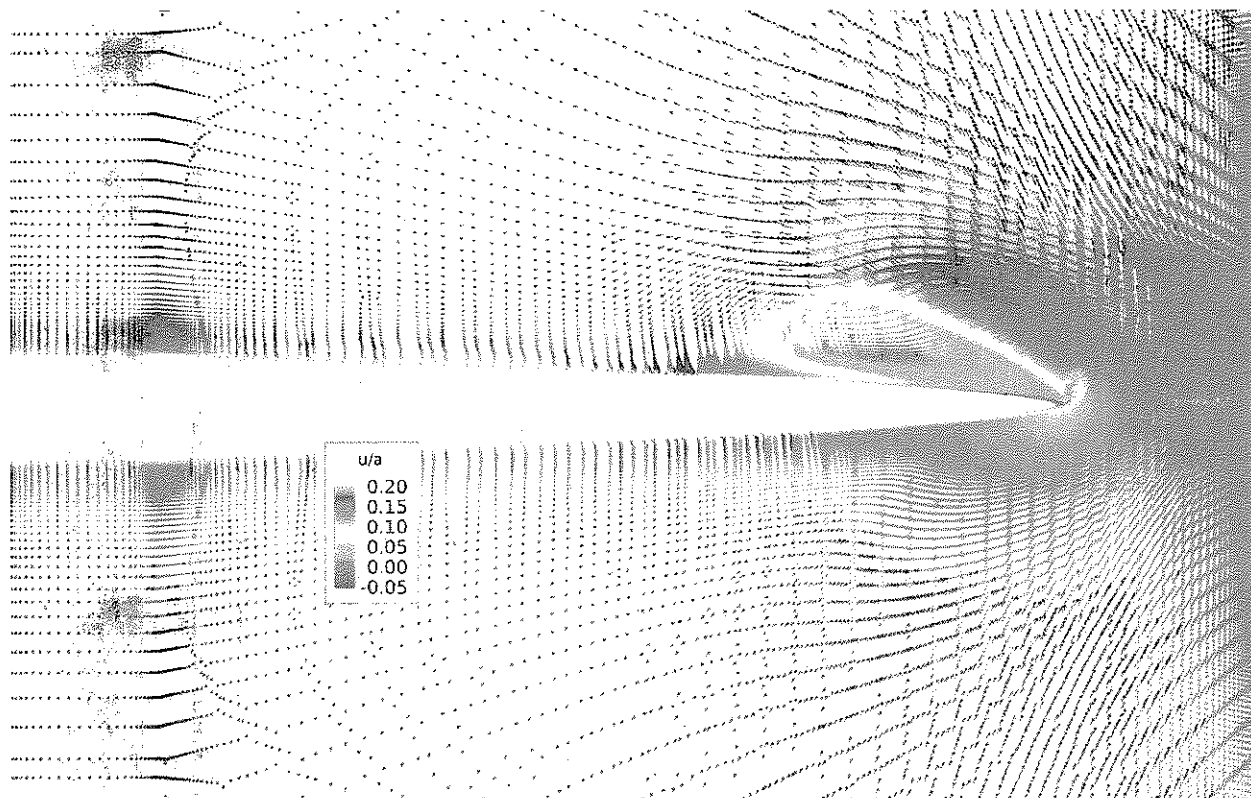
Pressure comparison and velocity vectors for cascade wind tunnel

Stability and Control Modeling

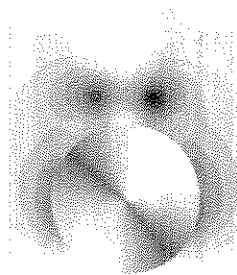
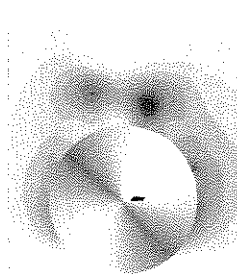
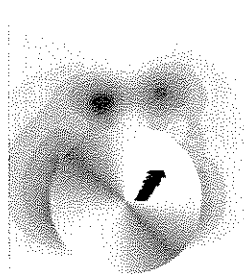
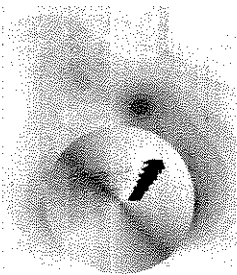
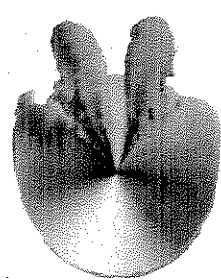
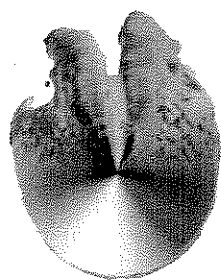
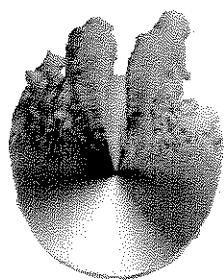


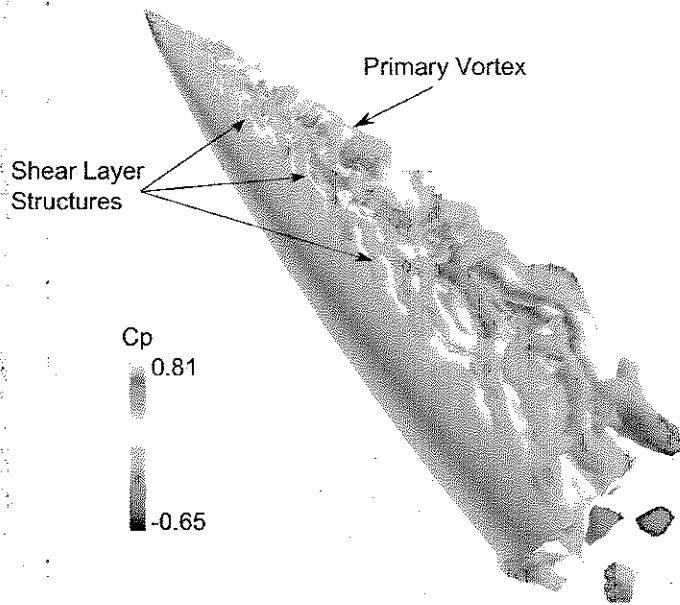




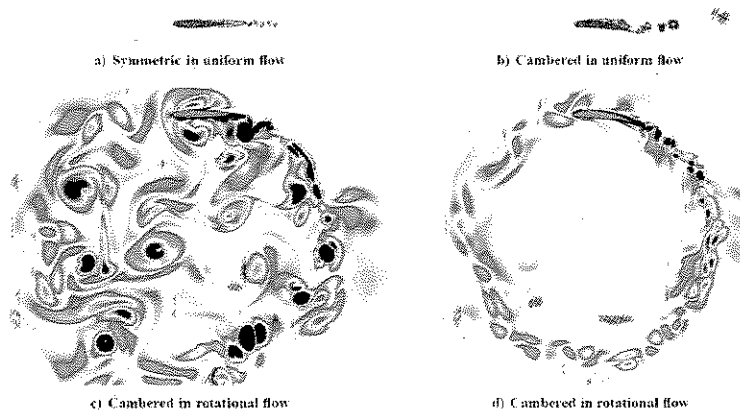


Tangent Ogive Nose



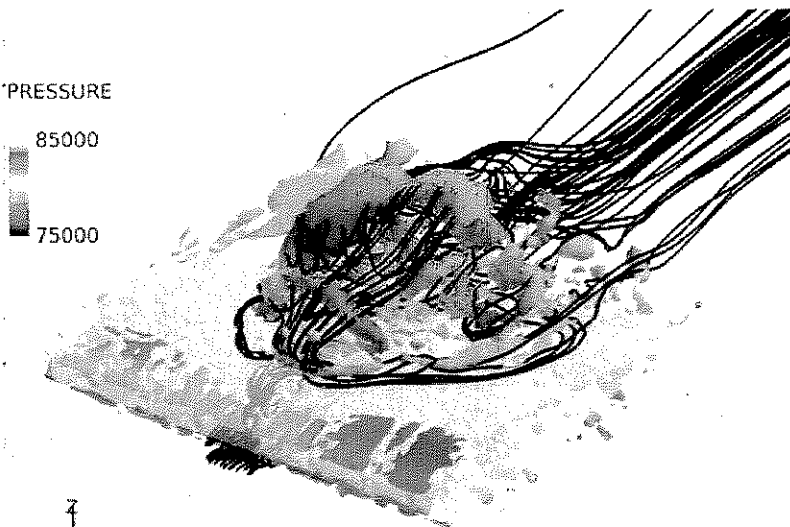


### Cycloidally rotating airfoil



### Ram air parachute

PRESSURE



PRESSURE

